THE RELATION OF THE CHEMICAL INDUSTRY OF NIAGARA FALLS TO THE WATER WORKS [1]

By John A. Kienle

As a prelude, and in order to show the relation existing between the electrochemical industry at Niagara Falls and the water works, the author has secured the following general statistics regarding the development of electric power at Niagara Falls by water from the Niagara River.

According to a recent estimate, the total potential power at Niagara Falls is 6,000,000 horse power. In 1916, from a total of 212,000 cubic feet of water per second, somewhat less than 56,000 cubic feet per second, or about 26 per cent, were diverted for electro-metallurgical industries and municipal purposes. The former consumed about 80 per cent of the total; that is, about 44,600 cubic feet, which generated 575,000 horse power.

A treaty between the United States and Great Britain authorizes Canada to divert for power purposes 36,000 cubic feet per second, and the United States 20,000 cubic feet per second. This unequal diversion was partly caused by the desire of the representatives of the United States to treat the approved diversion problem entirely from the standpoint of scenic conditions, and partly by the fact that part of the power from the Canadian plants was transmitted after development to the American side; also, possibly, by the fact that the city of Chicago was diverting water through its drainage canal upon which a small power development was located at Lockport, Ill. The available head at Lockport, Ill., is only about 30 feet, so that any water diverted at Chicago for power development represents an economic crime, for the reason that if this same water was diverted at Niagara Falls, it would produce over eight times as much power, besides any use of it that might be made in the future possible development in the St. Lawrence River.

Furthermore, only 7000 cubic feet per second are being used at present in the Chicago Drainage Canal, which means that 3000 cubic feet are not used, which, if allowed to be utilized to generate

[1] Read before the Buffalo Convention, June 11, 1919.

power at Niagara Falls would make available an additional 60,000 horse power. This would be equivalent to a saving of 394,000 tons of coal per year.

Power development at Niagara Falls. Until 1917, of the 20,000 cubic feet per second allotted to the American side only 15,600 cubic feet were used, as allowed by the Burton bill, but since then virtually all is used, which gives as the output for the companies on the American side an approximate 278,000 electrical horse power. There is being installed on the American side equipment to eventually increase this output to approximately 400,000 electrical horsepower, and, after that, by utilizing the head between the falls and the lake level and utilizing the same water, an additional 200,000 electrical horse power may be developed. The total drop from the Upper River to the level of Lake Ontario is about 300 feet, made up as follows: From the Upper River to the crest of the American Falls, 50 feet; the height of the Falls, 160 feet; and from the bottom of the Falls to the level of Lake Ontario, 90 feet.

Until recently Canada has been generating 360,000 electrical horse power, of which 125,000 electrical horse power were sold to the United States, so this country was consuming a total of 375,000 electrical horse power. Under construction now are plants which will bring the total for Canada up to approximately 700,000 electrical horse power.

According to the opinion of eminent engineers, at least half of the water in the Niagara River could be utilized without injuring the scenic effect; by installing the proper weirs and submerged dams, the recession of the Horseshoe Falls, which is now at the rate of 5 to 10 feet per year, could be obviated and the natural beauty of the Falls would be improved rather than impaired. This loss or waste of crest on the Canadian side has frequently been termed in public lectures on the subject "the suicide of the Horseshoe Falls."

The distribution of power at Niagara Falls is as follows:

	horse power
Electrometallurgical	82,500
Electrochemical (including chlorine and alkali)	44,000
Carbide, carbon and graphite products	65,400
Municipal	35,750
Miscellaneous (including paper manufacturing)	38,000
Abrasives	12,250
	278,000

Electrically made products. The number of products made at Niagara Falls is very extensive when we consider that the advent of the electro-chemical industry took place only twenty-four years ago. The first consumer of water power was the Aluminum Company of America, formerly known as The Pittsburgh Reduction Company. Its product, aluminum, enters into many industrial fields and finds ready application in the following list of products which are of essential use to the water works.

1. Automobile parts: Engine bed, crank case, transmission case, rear axle housing, running board, fans, seats, bodies, etc.
2. Electrical instruments: meter frames and meter covers.
3. Sheet metal: sheet auto bodies.
4. High tension feeder cables and bus bars.
5. Clock parts, bronze powders, pump parts, gaskets and fuses, as well as a deoxidizer of steel in the making of sound steel castings.

Another product of great importance is the one commonly known as "abrasives" which comes into the market as "alundum A" and "silicon carbide A." The trade names for the former are alundum and crystolon and these find special application wherever any material of high tensile strength or great hardness has to be ground or shaped. For instance, a manganese steel which cannot be cut by any tool, would still be a curiosity were it not for the aluminous abrasives which shape this material, so that such appurtenances as gears and burglar proof safes can be made from it. Besides grinding the above, this artificial corundum is used to grind crank and cam shafts, pistons, cylinders, forgings, castings, ball and roller bearings, all of which are to be found in any water works.

The silicon carbide abrasives, also known as carborundum and garnet products, are chiefly employed for grinding materials of low tensile strength, such as cast iron, brass, aluminum bronze, marble and granite, and wherever such a material is to be found in a water works it is certain that the abrasive has lent its aid to make the finished product. Every workshop in such an establishment always finds use for these abrasives.

Calcium carbide finds its chief use for making acetylene, which since the beginning of the oxy-acetylene welding industry has far outstripped its former use as illuminant. The latter, however, is still in great demand and many a water superintendent's night call involves the use of the carbide light. Also, as an emergency fuel, acetylene or calcium carbide plus water is of great help.

The various ferro alloys manufactured at Niagara Falls are ferro-silicon (FeSi), ferro-chromium (FeCr), ferro-tungsten (FeW), ferro-molybdenum (FeMo), and ferro-titanium (FeTi). Their greatest use is naturally in the direct war industries as shell steel, armor plates, projectiles, etc., but wherever high speed tool steel is required, one of these alloys will find its way into the manufacture of the specific material.

Ferro-silicon is used extensively as a deoxidizer for steel, from which it not only removes the oxygen but also any blow holes, both of which tend to weaken any casting, whether steel or cast iron. Approximately three-quarters of all steel made in the United States today contains ferro-silicon as one of its important ingredients.

Ferro-chromium makes a very hard steel which is used for ball bearings, dies, crushing jaws and tools. It needs no explanation how each of these finds its application in such an establishment as a water works.

Tungsten, vanadium, and molybdenum alloys are especially adapted for the manufacture of high speed tool steel, while the ferro-titanium is of great importance to steel and cast iron castings, bearings for pumps, and steam engines.

Speaking of alloys there is also manufactured at Niagara copper-calcium alloy which is used for deoxidizing copper, brass and bronze. The injurious effect of oxygen upon the electrical conductivity of copper is too well known to speak of it here.

Some of the products which find a more limited use in the water works are "refractories," such as crucibles, filtering devices, and extraction thimbles, made from alundum and carborundum, which enter into a laboratory equipment. Combination bricks for building purposes are also made from it.

Silicon, which is used in such alloys as silicon bronze, although not as good a conductor as copper, because of its greater strength is used for telephone and overhead electric wires.

Magnesium enters into the light weight casting and alloys industries, brasses and bronzes, and in the powder form is used as a pigment for paint and flash light powders. Of much greater importance is graphite, an excellent lubricant. Every battery contains it. Brushes and resistances for electrical devices use large quantities, and paint, lead pencils, hard rubber and pipe joint compounds are all outlets for this useful Niagara Falls product. Allied to the above is the carbon electrode industry which serves to supply the arc and searchlight and battery carbons.

It is to be borne in mind that here only those uses are enumerated as find application in some way, directly or indirectly, in a water works. To do full justice to each of these products would require too much time, for the field is broad and expanding continually.

Under the general heading of chemicals, there loom liquid chlorine and its related products, such as bleaching powder, chlorates and perchlorates; chlorinated organic compounds, as carbon tetrachloride, mono and dichlorbenzol; also, hydrochloric acid and sulphur chloride.

Chlorate of potassium is used for making matches; is contained in blasting powder, paints and fireworks (signal lights); and is also employed for welding.

Carbon tetrachloride is the well known main constituent of the pyrene extinguisher; and appears in the water works as an indicator in hydraulic instruments, notably the pitometer and chlorinator.

Sulphur chloride is used for vulcanizing rubber used as insulators, etc.

Other chemicals, like caustic soda and potash, which are manufactured along with chlorine are very useful. Caustic potash is used for special soaps and lubricants, but on account of its greater cost, it is not as freely applied as caustic soda, which is an essential material for soap and paper making, greases, lubricants, and oil refining. It is also a much used laboratory reagent.

The various leather belts used around the water works plant have, as a rule, been treated in the tanning process with such miscellaneous chemicals as bichromates, chromalum and sulphate, all manufactured at Niagara Falls. Ferro-chrom, phosphorus, sodium metal, hydrochloric acid, etc., all Niagara products, are extensively used in laboratories. Phosphorus particularly enters into the manufacture of phosphor bronze, an alloy, extensively used throughout the mechanical equipment of the water works, especially pumps, engines, meters, etc.

Formaldehyde and para-formaldehyde are excellent disinfectants and are also employed in the Baekelite process for making acid-proof varnishes and lacquers.

All glass used around the water works plant, in most cases, has embodied in its manufacture, sodium sulphate, which is a Niagara product.

MANUFACTURE OF CHLORINE AND BLEACHING POWDER

Quite naturally the major interest of the water works in the electrochemical industry at Niagara Falls centers in the two products, liquid chlorine and bleaching powder, manufactured by the electrolytic method. Therefore, a brief description of the two processes of manufacture will no doubt be of interest. For two main reasons the making of bleaching powder antedates the manufacture of liquid chlorine, first, the lack of a source of pure chlorine and second, the difficulties encountered in the liquefaction of the gas itself.

Chlorine was originally produced by the so-called chemical process, which resulted in a product of uncertain quality and strength. The development of the electrolytic method in its manufacture, which method has been the only one commercially used in this country, overcame this trouble. The difficulties of liquefaction, however, were not overcome until more recently, when refrigerating machinery and gas compression machines had been more fully developed.

Bleaching powder is a compound made from slacked lime and chlorine gas. The lime, which must be the best high calcium lime obtainable, is slacked with just the proper amount of water to make a dry compound (calcium hydroxide) known commercially as hydrated lime. To expose as large a surface of this lime as possible to the action of the chlorine, it is spread in ridges on the floor of a chamber or room, figure 1. These chambers are gas tight and are made of lead, concrete, brick, or even wood; the latter three, being less resistant to the action of the chlorine, are heavily coated with pitch. The chambers, several of which are required for a plant, are connected in series with acid-proof tile or lead pipe, so that the chlorine gas can be led into several of them in series. After the lime is spread on the floor the chlorine is turned into the chambers. The gas that is not absorbed in the first chamber is run into another chamber, and so on until the exit gases are free from chlorine.

In some cases, if a weak chlorine is being handled, the exit gases are run through a washing tower to remove the last traces. Chlorine is run into a chamber until the lime has absorbed 35 to 40 per cent. The gas remaining in the chamber is then drawn into a fresh chamber and the bleaching powder is shoveled through a chute in the floor into drums or barrels. Bleaching powder is a compound that is very sensitive to changes in temperature, and when exposed to the

air loses its chlorine strength rapidly. Even when sealed in drums decomposition occurs, especially in the hot summer months.

Liquid chlorine. While bleaching powder is very widely used and also a very necessary product, the demand for a more convenient form of chlorine is evidenced both by painstaking and costly development of the liquefying plants and the immediate success which liquid chlorine attained when introduced. Chlorine was liquefied commercially in Europe in 1889 or thereabouts. As said before,

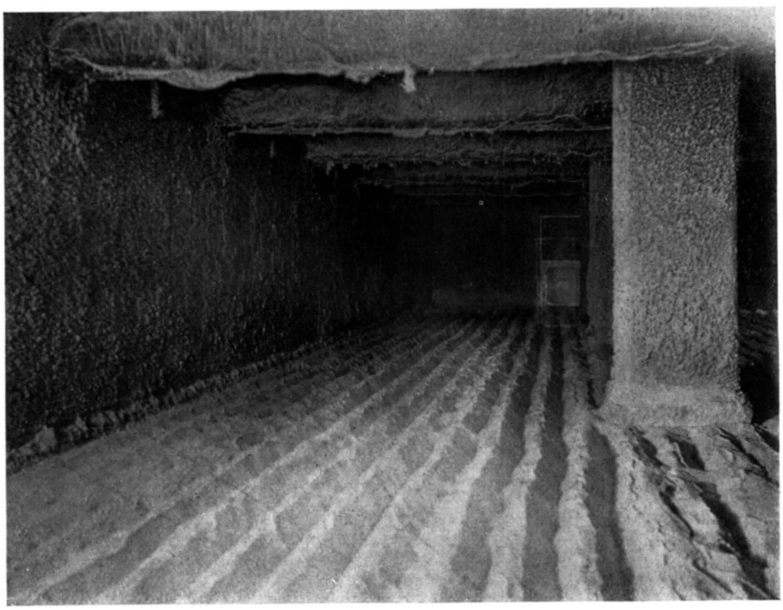

FIG. 1. INTERIOR OF A CHAMBER IN WHICH HYPOCHLORITE OF LIME IS PRODUCED

successful liquefaction of chlorine awaited a source of pure gas. This followed the introduction of the electrolytic cell, in which electric current breaks up common salt into chlorine and caustic soda, or more correctly sodium metal, which forms caustic soda and hydrogen with the water present.

The two types of cells in actual operation today are, first, the cell in which the two electrodes, cathode and anode, are separated by a porous partition or diaphragm; second, the cell in which there is

no diaphragm, but in which a mercury cathode dissolves the sodium metal as it is formed.

There are many modifications of the first type, which is generally known as the diaphragm cell. Those most widely used in this country are the Nelson, Allen-Moore, Wheeler, Townsend, Dow and Billiter. The main points of differences in these are in the disposition of the diaphragm and the anode, which is of Acheson graphite in all cases. With the exception of the Billiter cell, the

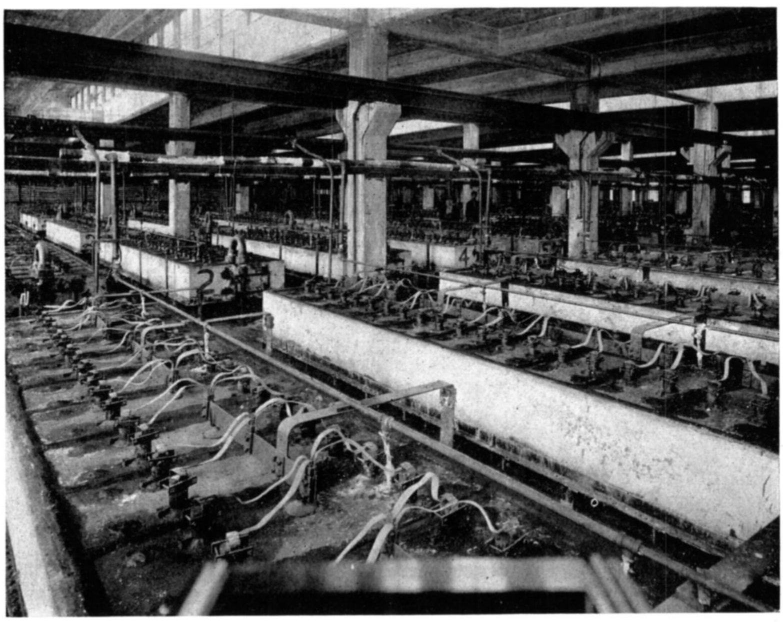

FIG. 2. ELECTROLYTIC CELLS FOR PRODUCING CHLORINE AND CAUSTIC SODA

diaphragms are vertical and made of asbestos cloth or paper, and in some cases impregnated with other materials to give uniform porosity. The Billiter cell has a horizontal diaphragm of asbestos cloth overlaid by a layer of barium sulphate and asbestos fiber, with several inches of brine above it. In this type of construction the chlorine and hydrogen cannot mix, as they are separated by a layer of brine. For the many points of differences in the above cells reference is made to the standard books on electro-chemistry, as this paper can touch only briefly on the general principles. An interior view of a large cell room is shown in figure 2.

In the second type of cell, known as the Castner cell, brine is decomposed and the chlorine gas is formed at the anode as in the other cells. At the cathode, which is a layer of mercury on the bottom of the cell the metallic sodium is dissolved by the mercury. The whole cell is rocked slightly back and forth by an eccentric cam and the solution of sodium in mercury runs into a compartment at the end of the cell where it comes in contact with water, forming caustic soda and hydrogen. As the cell tips back the mercury runs into the electrolyzing chamber to become saturated with metallic sodium again and the cycle is repeated.

The chlorine formed at the anode in all the various types of cells is much purer than that formed by the older chemical processes, and runs from 40 to 98 per cent of chlorine with small percentages of carbon dioxide, oxygen, and in some cases small amounts of hydrogen.

Pure chlorine gas can be condensed to a liquid at $-34°C.$ at atmospheric pressure, or at ordinary temperatures, say 15°C., by a pressure of 6 atmospheres. With gases containing a lower percentage of chlorine the pressure must be increased or the temperature lowered, or both, to give commercial yields of liquid chlorine. However, when the liquid chlorine has been separated from the other gases present, which do not liquefy under the above condition, it follows the gas laws for 100 per cent chlorine and contains at most only minute traces of other gases.

Chlorine when dry does not attack most of the metals, but before drying must be handled in lead or stoneware pipes. Before compression chlorine gas is dried in coke or stoneware packed towers by strong sulphuric acid which absorbs the moisture but dissolves only a small amount of chlorine.

To secure the necessary pressure of from 30 to 100 pounds per square inch for liquefaction various means are used. Some of the machines are similar to air compressors, figures 3 and 4. Lubrication of such machines is the big difficulty, as chlorine attacks all oils, forming hard or gummy chlorinated compounds. For this reason sulphuric acid is largely used as a liquid compressing agent, in spite of its disadvantages. In one type of machine a U-tube is used, in one limb of which a piston works; the other limb and the lower part of the U are filled with strong sulphuric acid. As the piston rises and falls in one limb the sulphuric acid rises and falls in the other forming a liquid piston which compresses the gas. The

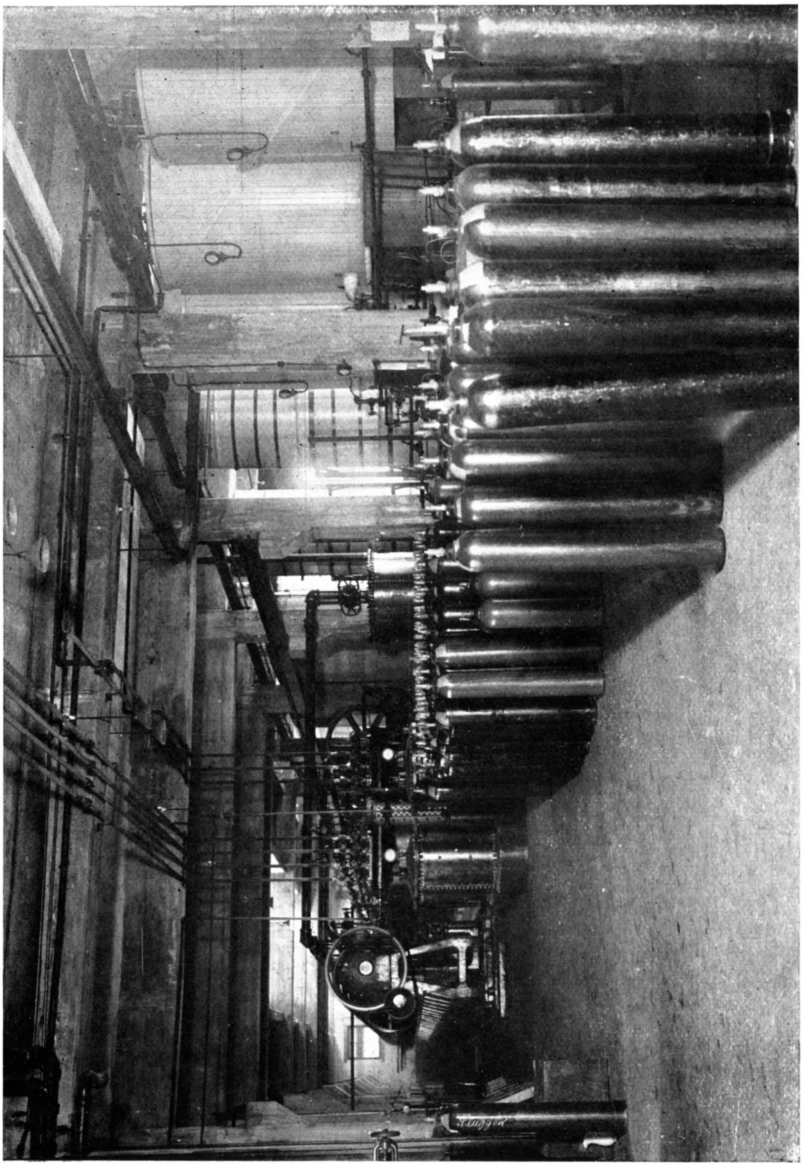

Fig. 3. View of the Compressors in a Plant Producing Liquid Chlorine

inlet and outlet valves are located in the top of the limb containing the sulphuric acid. Another type of compressor depends on the head of a falling stream of sulphuric acid to give the necessary pressure. A tower 75 to 100 feet high carries at the top an injector, through which a stream of sulphuric acid is pumped. The injector draws in chlorine gas, and as the bubbles of gas pass down the pipe to the bottom of the tower the head of sulphuric acid compresses them. At the bottom of the tower is a separating tank. The gas is taken out of a dome on the top and the sulphuric acid is drawn from the bottom and returned to the injector at the top of

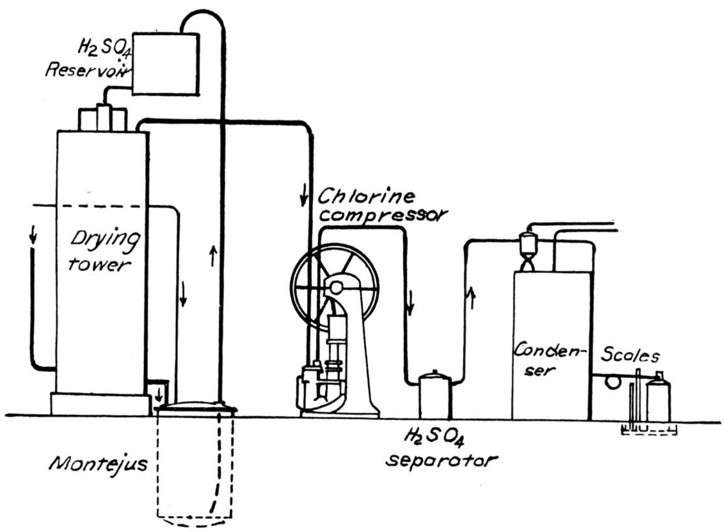

FIG. 4. SCHEME OF A CHLORINE-LIQUEFYING PLANT

the tower. This type of compressor gives a much lower pressure than the various reciprocating pumps. It is in reality an air lift turned up side down. The height of the tower upon which the pressure depends is naturally limited.

After compression, the chlorine gas is cooled by mechanical refrigerating machines, either of the ammonia or carbon dioxide type, to − 30° to − 70°C. At this temperature a varying quantity of the chlorine present in the compressed gas liquefies. The liquid is drawn off into cylinders, tank cars or other containers for shipment to the consumer. The chlorine contained in the waste gases is run into the bleaching powder chambers, or used in other chlorinating processes throughout the plant.

CHLORINATION OF WATER SUPPLIES

That chlorination of public water supplies has been the most noteworthy single contribution to the art of water purification in recent years, the author believes is conceded beyond question by all sanitarians. Furthermore, the effect of this method of water treatment in reducing the typhoid mortality of the country at large is attested not only by the statistics but by the increasing demand of public health authorities for this method of protection.

So much has been written on the subject that the author hesitates to present other than the general data to show the remarkable growth of the process, and consequently the important relation that this branch of Niagara's industry bears to the water works and to the health of the country. The writer wishes to call attention to the comprehensive treatise on the chlorination of water recently published by Joseph Race, which presents in a most concise manner many of the more important data on the subject.

The majority of the members present are, no doubt, familiar with the fact that chlorination of water by the hypochlorite of lime method was first carried out successfully in the United States by George A. Johnson at the Union Stock Yards at Chicago in 1907, and was almost immediately followed by the treatment of the Jersey City supply at Boonton, also with the lawsuit which it involved and the variety of expert opinion submitted as to the efficacy of the process, with the resulting court decision in its favor. Immediately following this there was a rapid growth in the use of this method, and by the end of 1911 approximately 500 water plants had been equipped with hypochlorite installation, and close to one billion gallons of water thus sterilized.

It is interesting to note at this junction that development of this art settled at once, and apparently for all time, the much mooted controversy between sanitary engineers on the question of the suitability and ultimate efficiency of rapid and slow sand filtration as the correct means of water purification. The doubt that had previously existed as to the quality of water delivered from rapid filters was at once eliminated by the bactericidal effect of chlorination upon the effluent, and the process became a very necessary adjunct to all filter plants.

It is perhaps purely coincident that at this stage of the development of the chlorination of public water supplies there was a tem-

porary interruption in the downward trend of the country's typhoid rate, extending into the year 1912. The author is inclined to believe that the use of hypochlorite of lime as a sterilizing agent had about reached its maximum usefulness by reason of the fact that the majority of those water plants, where the proper control and supervision of hypochlorite application was possible, had by this time been equipped with hypochlorite plants. The many inherent disadvantages in the use of this chemical for sterilization of the smaller city supplies is well known and it is only necessary to cite the most recent evidence in the case of Xenia, Ohio, to substantiate the above claim.[2] Xenia had a rather severe typhoid epidemic, notwithstanding the application of hypochlorite, due solely to the failure of the attendants in charge to realize or understand that hypochlorite loses its chlorine strength rapidly in storage and that the deteriorated lime powder has no effect on the bacterial content of the water. The author unhesitatingly makes the deduction that it is extremely fortunate for the country's welfare that the use of liquid chlorine was developed at this stage of the campaign against preventable diseases.

The American Water Works Associatior was first advised of this newer process at the Minneapolis convention in 1912. The first to use liquid chlorine was Major Carl R. Dowall at Fort Myer, immediately followed by commercial experiments at Niagara Falls, Wilmington, Philadelphia and Brooklyn, by several investigators operating independently.

Although the increase in the use of hypochlorite was quite rapid, following its application at Boonton, the rate of growth of the liquid chlorine process was even more pronounced. From only one water plant, viz., Niagara Falls, equipped at the end of 1912, the number at the end of 1918 had jumped to a total of approximately 2500. The more populous urban districts throughout the country, particularly those states where the State Boards of Health are most active and efficient in their work, are the ones which have progressed most rapidly. No doubt this is largely due, as stated by George A. Johnson in his excellent paper,[3] "The Typhoid Toll" to the failure of the various State legislative bodies to provide suitable laws and appropriations for the health boards properly to conduct

[2] See JOURNAL, June, 1919, p. 167.
[3] See JOURNAL, June, 1916, p. 249.

educational and investigative work, and more particularly a thorough supervision of the quality of water supplied to the communities.

In 1907 the United States Census Bureau reported that the typhoid fever death rate in the registration area with a population of 41,-758,000, was 30.3 per 100,000, and the estimated number of deaths within the year for the entire country was approximately 30,000, and in that year there were no chlorinated water supplies.

In 1917, the latest year for which figures are available from the United States Public Health Service, the rate had dropped to 12.3 per 100,000, with the estimated number of deaths stated at 13,000, and in this year there were at least 2000 public water supplies that were chlorinated. There were 17,000 lives saved from death by typhoid in one year, to say nothing of other water-borne diseases or the increase in vital resistance to other diseases.

Perhaps these figures will impress themselves more forcibly by the simple statement that the chlorination of water has been the major factor in saving more lives in the United States since its inception 10 years ago than were lost by the United States forces in the world war. Think for a moment just what this means expressed in vital capital; 17,000 lives at a value of $7500 each, which figure includes allowance for lost wage, medical attendance, lowered vitality, etc., in the proportionate case rate, result in a saving of over $125,000,000 annually. As the figures available represent only the mortality statistics of the so-called registration area, the estimated population of which is approximately 70,000,000 people, it is apparent, if the total population of the United States be assumed at 110,000,000, that there is left approximately 40,000,000 population for which there are no available statistics to show the death rate.

Perhaps a clearer view of the possibilities of improvement in the typhoid situation by the simple chlorination of water may be obtained by a study of the total number of public water supplies which exist in the United States. Obviously, it is difficult to get any definite figures on the exact number of these, but a careful investigation a few years ago indicated that the number of such supplies was something more than 7500. If we take the number of supplies that have been stated as being filtered or chlorinated at 2500, it is apparent that but one-third of the number of supplies has this protection. It is also clear that the balance, or two-thirds, must feed those smaller cities in the less populous districts of the

United States. If we assume the total urban population served by the above number of water supplies at 60,000,000 and the number receiving chlorinated or filtered water is, according to best estimate obtainable, 40,000,000, there is a balance of 20,000,000, the major portion of whose lives are more or less in danger by the failure of the authorities to chlorinate the water.

It is obviously not fair to take the typhoid statistics of the total registration area as a basis for computing the possible improvement that might occur if these 5000 water supplies were chlorinated, for the reason that the total statistics include the death rates occurring

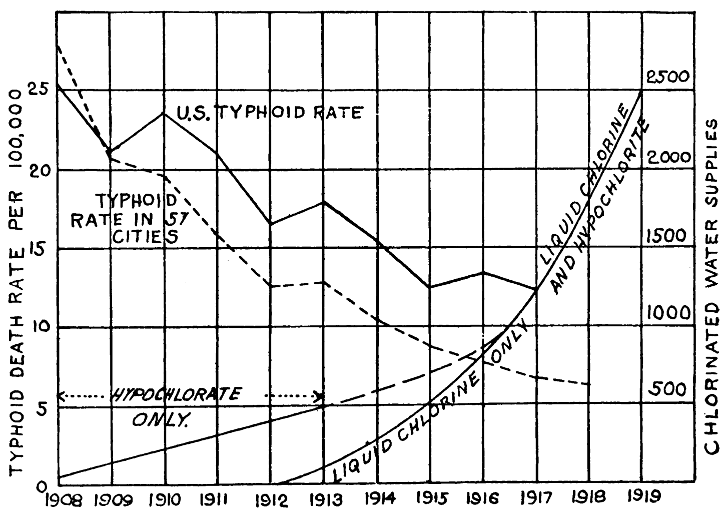

FIG. 5. RELATION OF CHLORINATED WATER SUPPLIES TO TYPHOID DEATH RATE

in the rural districts. For this reason it seems very much more logical to take the mortality rate of the urban population. In order to obtain an idea of the effect of chlorination on the urban typhoid statistics a curve showing the death rate in 57 principal cities, compiled from the statistics of the *Journal of the American Medical Association*, is shown in figure 5. From this it is seen that the average typhoid rate in these cities in 1908 was 28 per 100,000. In 1918, after 10 years of gradual improvement in the quality of water delivered to the consumer the rate dropped to 6.2 per 100,000.

Now, if we assume that the death rate in those municipalities not receiving purified water approximates even the low average

condition existing in the registration area in 1917, it becomes apparent that the annual loss of life in the 20,000,000 of urban population would represent a total number of deaths annually of not less than 2500. Reducing this to vital capital, it would represent a loss annually of $18,750,000. A corresponding investment valued at 6 per cent is $312,500,000. The cost of installing 5000 additional chlorination plants would certainly not exceed $3,000,000, or only 1 per cent of the capitalized value of the lives lost. The interest, depreciation and operation charges would not exceed $750,000. Compare this also with the annual loss in vital capital.

It has been aptly stated that the chlorination of public water supplies is the cheapest municipal insurance that can be obtained, the average annual premium amounting to not more than 40 cents per million gallons of water treated, or, for a municipality of 5000 or less, an annual expense to the municipal government of $150 per annum ($36.50 operating, and $120 depreciation at rate of 20 per cent) or a cost per capita based on the same figure of 5000 population, of 3 cents.

In the State of New York in 1908 the typhoid death rate per 100,000 was 16, while 10 years later it had fallen to 5.4 per 100,000. Approximately 1200 lives were saved in one year from death by typhoid. There are in the State 510 public water supplies, serving a population of 8,700,000 out of a total population of 10,682,000. Of the total number of water supplies, 125 are purified by filtration or chlorination or both, and the population served is approximately 7,000,000, leaving 385 supplies serving a population of 1,700,000 without water supply properly protected, or an average population of 4400 per supply, which corresponds favorably to the assumption regarding the country's average condition in the preceding part of the paper. In Pennsylvania a death rate of 32.4 in 1908 was reduced in 1918 to 10 per 100,000. Out of a total population of 8,750,000 in the State, less than 4,000,000 were receiving purified water. The total number of supplies amounted to about 1200, with less than 140 having proper protection.

Connecticut, with 104 public water supplies only 24 of which are today being treated, shows a reduction in the death rate from 18.4 in 1908 to 5.3 per 100,000 in 1918.

New Jersey, snuffing out the lives of 408 of its citizens in 1906, reduced its loss in 1918 to 162. Are not these 162 people worth an effort when it is considered that out of a total of 184 surface water

supplies (69 underground having been eliminated from the count) only 36 are chlorinated.

There have been prepared two line charts, figures 6 and 7, showing the reduction in typhoid, first, in five of the principal cities of the United States where the water supply is both filtered and chlorinated, Philadelphia, Baltimore, Pittsburgh, Cincinnati and Minneapolis; and second, five other principal cities—New York, Jersey City, Buffalo, Chicago, and Milwaukee, where the only treatment the water receives is chlorination.

The author's purpose in presenting these charts is mainly to show that so far as reduction in typhoid mortality, as related to water supply improvement, is concerned, chlorination is quite as effective as filtration. It is not, however, his intention to create the impression that chlorinaton is to be in the slightest way considered as a substitute for filtration. There are today, no doubt, many chlorinated water supplies that should be filtered. The use of chlorine does not in any way change the physical or chemical characteristics of the water. It will not rectify the water from the standpoint of appearance as it will remove neither turbidity nor other suspended matter, while its effect upon color is almost negligible. The important point, however, is its known bactericidal action and the absolute safety of the treated water for drinking purposes. The filtration of water has proven its worth so thoroughly and frequently that it needs no further evidence of its value here, its place in water treatment is vital, but just as chlorination is not a substitute for filtration, so also filtration should not be considered a substitute for chlorination. The dangerous bacteria still lurking in the filtered effluent should be destroyed by chlorine and the water rendered sterile.

Niagara Falls has contributed much to the general welfare of the country but its contribution in safe-guarding of public health through its relation with the water works stands supreme. It has available the power and facilities to do considerably more, yet what it can accomplish in the future rests with the State and municipal health authorities. Where there is a lack of appreciation by these the responsibility must logically be assumed by the water works superintendent.

In concluding the author acknowledges, with full appreciation, the courtesy and assistance extended by the staff of the Wallace & Tiernan Company and the Niagara Alkali Company in collecting many of the data entering into the preparation of this paper.

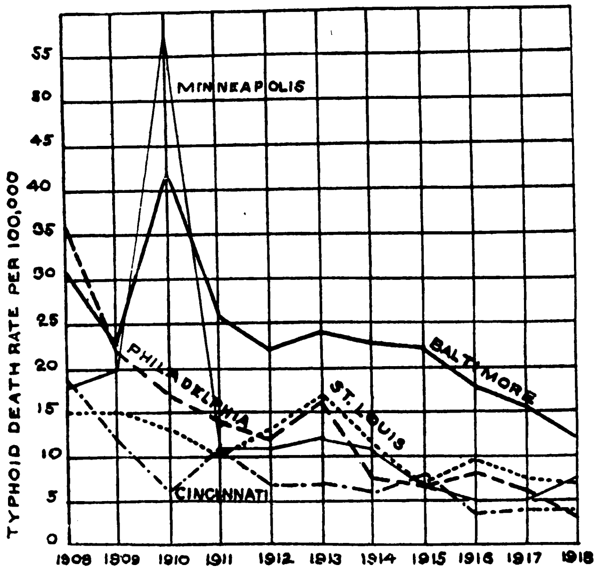

Fig. 6. Typhoid Death Rates of Cities with Filtered and Chlorinated Water

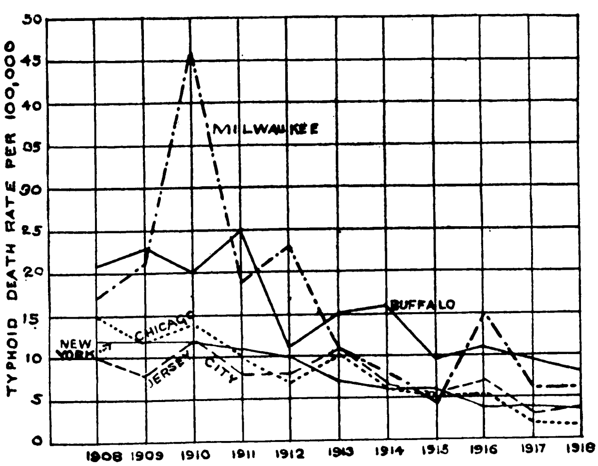

Fig. 7. Typhoid Death Rates of Cities Using Water Treated only with Chlorine

DISCUSSION

Lieut. Col. George A. Johnson: Ten years ago little was known of the advantages which would accrue from the use of chlorine in the sterilization of water. Something had been done in sterilization of sewage, but scarcely anything in the way of water sterilization. An almost unparalleled opportunity for a spectacular exhibit of the advantages of chlorination was offered at the Chicago stock-yards where a very unique water problem was presented, and the immediate advantages of this treatment became apparent. The adoption of the chlorination treatment was widespread, but its use was clandestine in many cases because of the natural aversion on the part of many city officials to the use of chemicals in any form in the treatment of water. It was at first unwisely used in many instances, yet the advantages which have followed the almost universal adoption of the chlorination of water are tremendous.

It is difficult to measure exactly the part that chlorination has performed in the reduction of water-borne disease. It is an exceedingly difficult thing to explain it plainly and convincingly, because there are so many other influences that enter into the reduction of typhoid fever. There is no question but that we must be fair-minded enough to realize that medical treatment is better now than it was ten years ago; and, too, people are more sensible in their habits. But nevertheless there is a great amount of credit to be given to chlorination in the reduction of water-borne disease.

The author is correct and fair in stating that chlorination is not a substitute for filtration; it is not, and never will be. Probably the most pernicious influence that chlorination has had has been its adoption in cases where the water first should have been filtered. Wherever a given water contains suspended matters, particles of vegetable debris, and what-not, chlorination treatment alone is liable to be dangerous, because it gives a sense of false security to the user, who believes that it is to be relied upon to the extent of 100 per cent efficiency provided he gets enough in, and gets it in consistently and constantly. Now that is not so. Bacteria, or at least bacteria of a disease-producing character, can become imbedded within the particles of suspended matter so that notwithstanding the action of the chlorine, they pass on to the mouth of the ultimate consumer and cause disease and death.

There is no question that the real ideal method of water treatment is, first, complete clarification by filtration, followed by sterili-

zation with chlorine, and that is what the American municipalities are coming to today, the speaker believes; it is at least what they should all come to. Chlorination alone is about as bad as filtration alone, indeed, it is even worse. It is preferable to depend upon a filter plant to give maximum protection than on chlorine alone; but the two together furnish, it seems to the speaker, 100 per cent protection, whereas neither one of them alone accomplishes that. There is, of course, a possibility of having waters in some cases that are free from suspended matters and can be treated freely and thoroughly with chlorine alone; but by and large, we ought to come to the practice of filtration first and chlorination second. They are worth their cost to any municipality, because they do give 100 per cent protection against water-borne disease.

M. N. Baker.—There can be no question in the minds of any that have followed either the development of this matter or the excellent paper that has been presented, that chlorination is one of the sanitary marvels of the age. Of course, as has just been suggested, chlorination and filtration ought to go together and share the credit for all the typhoid reduction that has taken place; but either alone, and certainly the two together, have played their part in bringing about this reduction, and almost the entire part in many instances. It is not so very long ago that a typhoid death rate of 20 or over per 1000 would cast a shadow of doubt upon the purity of a water supply. It is shown now by the figures that the American Medical Association publishes in its *Journal*, to which the author referred, that there are a considerable number of cities whose typhoid death rate is well below 5, and a few that have been down to 2, or even below that; so that we are certainly making marvelous progress. Water works men have nothing upon which they can more justly congratulate themselves than this reduction in the typhoid death rate, in which they have played so important a part in the last few years.

Henry P. Bohmann: Perhaps the members of this Association will be interested in Milwaukee's experience in treating its water supply. The city gets its water from Lake Michigan; it is not filtered, but chlorinated. In 1910, there was a typhoid epidemic and bleach was first used at that time and the epidemic was promptly checked. Later on we changed to liquid chlorine. It was noticed from time to time that a very obnoxious taste appeared

in the water, which we of course attributed to the use of chlorine. But it was also noticeable that when the quantity of chlorine used was cut down, the taste did not immediately disappear; it took several days for this to happen. After making further investigation it was found that the taste only appeared when the wind was blowing in a certain direction. When the wind blew from the southwest it carried sewage toward the intake, and the taste became so obnoxious at such times that it was impossible to drink the water, in fact, some of the patrons of downtown restaurants refused to pay for their meals and threw the dishes on the floor.

At the last convention a member of this Association gave it as his opinion that sewage discharged from a coke plant entered their water supply and that, together with the chlorine formed compounds that produced taste. An investigation was made along that line. In the city, sewage was being discharged from a coke plant, and experiments with that sewage proved that it was possible to reproduce the exact taste in the city water supply. Experiments were also made with benzol, naphthalene, etc., and with each one of these it was possible to reproduce the identical taste observed in the water supply. Samples were taken from the different tanneries, packing-houses and intercepting sewers, to try to reproduce this taste with their sewage, and this was found not possible except with sewage of a coal-tar derivative nature. Experiments made with phenol showed that one part of phenol would impart taste to 500 million parts of water if chlorinated. There is a phenol plant doing work for the Government about 13 miles from the intake. Investigation was made there, and it was learned that about 2200 pounds of concentrated phenol was getting away from that plant daily, an amount sufficient to pollute the whole lake.

The officials of that plant claimed that they were doing Government work and the water department could not possibly interfere with them. The department enlisted the aid of the Governor, telegraphed to Washington, and persuaded specialists of repute to go over the experiments that the department had made. Fortunately the armistice was signed at about that time and that plant was closed. However, that was the only thing that saved the situation. When the department first came out and accused different companies of being the cause of the pollution of the water supply they published half-page advertisements in every daily and weekly paper in Milwaukee denying it. The speaker had the satis-

faction of having the manager of the phenol plant openly admit before the Chemical Society that they were undoubtedly the cause of the trouble, and that through the department they had learned a few things about their own business that they did not know before. Since then the plant was closed, and the coke plant has diverted into other channels its sewage which formerly reached the intake; there has been no taste since that time. The department fully demonstrated the fact that a taste like phenol or iodoform is not necessarily due to chlorine treatment. The chlorine has to be in combination with sewage of a coal tar derivative nature. It is possible by boiling water to expel the chlorine taste, but it is impossible to boil out that particular taste because it is due to a substance that has a higher boiling point than water. The subject is discussed at length in the last annual report of the department.

Maurice R. Scharff: It may be interesting to compare the author's statement as to the growth of the use of the liquid chlorine treatment in America with the situation in that respect in France. Lieut.-Col. Edward Bartow, in charge of the laboratory work of the American Expeditionary Force in France, started in the Fall of 1917 in cooperation with a well-known French scientist a series of experiments on the use of liquid chlorine in Paris, and succeeded in showing to the satisfaction of his companion and that of other French sanitarians and engineers, that it was possible to purify raw water from the River Seine so as to make it bacteriologically safe. It was interesting to observe that those experiments were commented on by the French press as experiments along an entirely new line, and so far as one could gather from those comments, the use of liquid chlorine in the United States for a long period of years prior to that time was not known in France. Not only did this seem to be true of the press in general, but the speaker had an opportunity to examine a number of reports on water sterilization for different municipalities by prominent French engineers and sanitarians; and although they gave consideration in their reports to the use of ozone, ultra-violet rays, and similar processes, he did not see any mention of the use of liquid chlorine. The impression made by Lieut.-Col. Bartow's experiment was so excellent that as a result it was possible to introduce liquid chlorine disinfection into a number of municipal supplies upon which the American Army depended.